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RESEARCH TRANSLATION

Rocketsonde Wind Measurements Up to the Mesopause in Sardinia

M. SCHURER (ed.)

OFFICE OF AEROSPACE RESEARCH
United States Air Force

T-G-248

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45 BEACON STREET
BOSTON, MASSACHUSETTS
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ROCKETSONDE WIND MEASUREMENTS UP TO THE MESOPAUSE IN SARDINIA

Translation of

Windmessungen mittels meteorologischer Raketen bis zur Mesopause in Sardinien

by

M. Schurer, (ed.)

German Aerospace Research Establishment (Munich), Report on Federal Ministry of Defense Contract No. T-472 BMVtdg, April 1965.

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L. G. HANSCOM FIELD

BEDFORD, MASSACHUSETTS

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ROCKETSONDE WIND MEASUREMENTS UP TO THE MESOPAUSE IN SARDINIA

H. Schurer, ed.

I. Task Description

1. Research Contract, Fed. Min. Def., T II, 3:

The Institute for Physics of the Atmosphere, German Aerospace Research Establishment (GARE), Munich-Riem, on the basis of its application of 5 March 1964, received from the Federal Minister of Defense a research contract, "Rocketsonde probes in Sardinia." The contract is numbered T-472 BMVtdg.

2. Task Description:

The studies* on the stratification and variation of the winds aloft up to the mesopause with Arcas rocketsondes are to be implemented. The seasonal change in wind regime from westerly to easterly is to be detected.

2.1 With an eye to the implementation of this task, GARE (Munich-Riem) had already assigned several members for instruction and collaboration in the test project "Testing of geophysical measuring rockets in Sardinia, October-November 1963," conducted by Test Sections 81 and 91 of the Federal Defense Forces. Details of this test project can be found in the test report "Geophysical measuring rockets in Sardinia, Oc ober-

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*[Projected in a previous report: Tr. note.]

-November 1963," Test Section 91 of the Federal Defense Forces, Field Station B, 24 February 1964. The analysis of the meteorological data, especially the wind diagrams, was made by GARE separately, after the measured data were made available. These rocket shots gave GARE a good general view of the procedures, rules, and conditions of rocket firing on the Italian range, Salto di Quirra, on Sardinia.

2.2. In addition, Dipl.-Ing. Liess (Test Sec. 91) kindly conducted a course of instruction in rocket launch technology and the operation of the launcher for Arcas rockets, from 1 April to 4 April 1964 in Meppen.

2.3. The German Weather Service participated in the experiments and made its practical experience available (see subsecs. 5.1 and 5.3).

3. Responsibility for Implementation:

Professor H. G. Müller was in charge of the scientific supervision of the entire research contract. Dipl.-Phys. M. Schurer was the specialist in charge of the measurements.

4. Preliminary Work:

4.1 After detailed discussions with Dr. aufm Kampe, Fed. Min. Def., Div. T II, 3, a draft of an agreement with the Republic of Italy was prepared for the use of the Salto di Quirra Missile Range of the Interservice Experiment Area on Sardinia, dated 5 March 1964. Personal negotiations with the German Ambassador in Rome and at the Italian Ministry of Aviation with the competent specialist, Col. Ghersini, on the definitive range stipulations were completed 31 March 1964. At the same time, organizational agreements were made with the range commander, General Costa, and the field facilities were inspected. The preliminary negotiations in Sardinia were completed by conferences with the commander of the German training detachment in Decimomannu concerning the support of the mission in all aspects of ancillary and transportation services.

4.2. After contacts with the agencies concerned, and bearing in mind the assigned scientific research task, it was planned to carry out three to four rocket probes per day from 20 April 1964 to 9 May 1964.

The schedule foresaw assembly and installation of all experimental equipment from 15 April 1964 to 19 April 1964; removal, packing, and return transport were planned for the period from 10 May 1964 to 15 May 1964. The schedule was maintained in all respects.

5. Staff and Equipment:

5.1. GARE, Munich-Riem, Institute for Physics of the Atmosphere, as the contractor for the research project, could not conduct the experiments with its personnel alone. The Geophysical Advisory Service of the Federal Defense Forces, Test Sections 81 and 91, and the German Weather Service (GWS) made personnel available, so that the number of participants by affiliations was as follows:

German Weather Service	2 participants
Geophysical Advisory Service, Federal Defense Forces	6 participants
Test Section 81	1 participant

Test Section 91	2 participants
German Aerospace Research Establishment	7 participants

5.2. The locally incurred organizational and administrative responsibilities, such as negotiations with German and Italian agencies on the use of the range, organization of the staff, procurement of equipment and supplies, transportation, accommodation of the participants, provisions, and shipment of supplies, were met by the present writer and by the representative of the Fed. Def. Min., Mr. J. Plank.

5.3. Assignment of Personnel.

Chief of Research on behalf of Prof. H. G. Müller, GARE Institute of Physics of the Atmosphere	Dipl.-Phys. M. Schurer
Meteorological and Technical Adviser	Dr. W. Attmannspacher, GWS
Interpreter and Escort of the members of the Federal Defense Forces	Mr. J. Plank
Launcher Group -	
Chief of Launch Operations	Dipl.-Ing. W. Liess, Test Section 91
Assistant Chief	Ing. J. Schwarz, GARE
Members	Mr. S. Buhl, GARE Mr. A. Finkenzeller, GARE Mr. Witzke, Test Section 91 (Launch training of GARE personnel)
MSQ-1A Radar Group -	
Chief of Operations	Mr. Le May, GARE/Fed. Def. Min.
Assistant	Ing. Branns, GARE

Members	Mr. Riess Mr. Happach, Geophysical Advisory Service, Federal Defense Forces Mr. Wégé, Test Section 81 (In charge of return transport from Sardinia of equipment of Test Section 81)
Computing Group - (Wind analysis and wind-weighting of rocket trajectory)	
Chief	Ing. J. Lidl, GARE
Members	Mr. Jost, GWS Mr. Ebertseder, Geophysical Advisory Service, Federal Defense Forces
Drivers/Generator Servicemen	Mr. Grossmann Mr. A. Renner

5.4. Equipment.

Rockets. All the rockets used were U. S. Arcas Model 1 meteorological rockets with ROBIN sondes. The rockets, the stock remaining on hand from the fall 1963 test project, were stored in an ammunition bunker of the German Air Force Training Detachment in Decimomannu. The total stock at the beginning of operations was 80 Arcas rocket motors and 60 Arcas nose cones. For the nose cones, 60 ROBIN mylar balloons in factory packing were also available. The German AF Training Detachment released 45 Arcas motors and 45 Arcas ROBIN nose cones to GARE. An Italian civilian shipping firm was engaged to transport the rockets and nose cones from the German AF Training Detachment at Decimomannu to the Italian Salto di Quirra Missile Range (130 km away), where they were stored in an ammunition bunker near the launcher.

Launcher. The launcher with its accessories and tools was at Test Section 91 in Meppen. The fall 1963 experiments had shown that various changes had to be made in the construction of the launcher; for example, means of finer adjustment in azimuth and elevation, elimination of excessive bearing play in the turntable platform, better means of fastening to base plate, and new firing mechanism. Test Section 91 (Dipl.-Ing. Liess) implemented all the changes and provided the forms for the firing experiments and a precise specification of the safety zone. The launcher and all needed accessories were transported by ACG 61 to Decimomannu by air.

MSQ-1A radar. The Federal Defense Forces MSQ-1A radar, consisting of four special trucks (radar truck, computer truck, parts truck, and cable truck) was available for tracking the ROBIN mylar balloon with reflector. Originally, the radar was used for tracking and monitoring the trajectories of high-speed flying objects; it was transferred from U. S. Army stocks to the Federal Defense Forces in 1962 and overhauled by Mr. Le May, a U. S. radar expert. The radar had already been used in the test project in the fall of 1963, and thereupon was kept for the winter in storage warehouses of the Italian Air Force in Elmas, on Sardinia, until it was employed again in the spring of 1964. Two diesel generators (50 kv, 60 Hz) were associated with the radar. As a replacement for periods of repair and overhaul of these two, a third generator was airlifted from the GARE facility in Oberpfaffenhofen to Decimomannu. The AF

Training Detachment in Decimomannu provided the transport from Elmas to Decimomannu and the field inspection and maintenance of the vehicles.

Other vehicles. In addition to the abovementioned special vehicles for the radar, an MAN 5-ton truck and two 1/4-ton GP trucks of the Federal Defense Forces (AF Motor Regiment 2) were available for transportation of personnel and equipment. These vehicles were also located at the German AF Training Detachment in Decimomannu as a result of the fall 1963 test project. The vehicles were inspected and prepared for service there as well.

Other equipment and material. Tools and the most important replacement parts for the radar and for rocket launching were airlifted in various large packing cases to Decimomannu, from the stocks of both GARE and the Federal Defense Forces. Among the stocks still in storage at Decimomannu from the fall 1963 test project were equipment and stores for balloon soundings to determine the wind; balloons; radar reflectors; balloon parachutes; and inflation equipment. Additional items were provided by GARE, as well as all the office and analysis equipment and supplies of the computing group for wind determination, wind-weighting computation, and computation of the individual launcher firing angle. Determination of the wind and computation of the wind-weighting of the rocket trajectory were required both in order to keep the trajectory and point of impact of the rocket in the prescribed safety zone and in order to reach the maximum apogee height with the rocket.

Twenty motor-fuel barrels for gasoline and diesel fuel were borrowed from the Federal Defense Forces. The fuel for all the vehicles was provided by the German AF Training Detachment in Decimomannu.

6.

An excellent cooperation was achieved despite the variety of the source agencies and employers, as well as the novel and fairly difficult problems. The German agencies granted every conceivable assistance, even where unforeseen difficulties arose. Only the morale of the understaffed measuring and auxiliary personnel made the successful implementation of the program possible.

Special stress should also be laid on the excellent cooperation with the Italian military agencies.

General Costa, the commander of the Salto di Quirra Missile Range, Col. Scifo, Col. Ghersini, Maj. Bianchini, and the Italian Weather Service in Elmas supported the experiments in an extremely accommodating and effective manner. All the other Italian agencies also responded kindly and helpfully.

II. Implementation of the Experiments

1. Salto di Quirra Missile Range:

The Salto di Quirra Missile Range is located on the southern half of the east coast of Sardinia and is essentially divided into two main areas: the area of the launching bases, Capo San Lorenzo, which borders on the sea with facilities for launching over the open water; and the command post, Perdas de Fogu, at about 1000 m msl and 40 km inland to the northwest.

This last-named headquarters, called the Poligono, has complete control of the missile launching and the monitoring of the safety of the land and sea areas; the latter is performed by radar and optical observation stations. Perdas de Fogu can be reached from Capo San Lorenzo by helicopter or over rough mountain roads. The personnel and all the equipment of the GARE experiment group had to be taken to Capo San Lorenzo. The German AF Training Detachment in Decimomannu (assembly point for personnel and equipment) is located 130 km from Capo San Lorenzo. The road follows a mountainous route, part of which is very steep.

2. Advance Party:

The advance party, consisting of the present writer, the representative of the Federal Defense Forces (also interpreter) Mr. Plank, and three drivers, arrived in Decimomannu on 7 April 1964.

There, all the equipment and stores that had either been stored in Sardinia or again flown in from the Federal Republic by the German AF was received and assembled for transport to Capo San Lorenzo. They were moved to the Capo San Lorenzo range in a convoy (12 vehicles) with the AF Training Detachment in charge.

During the week of preparations (7 April to 14 April), the advance party undertook the following tasks:

a. Procurement of quarters and arrangement of meals for all participants at Capo San Lorenzo, as well as at Muravera, 23 km away.

b. Arrangement of the emplacements for the MSQ-1A radar and the Arcas rocket launcher.

c. Transportation of the rockets from Decimomannu to Capo San Lorenzo by a private trucking firm with police escort and storage of the ammunition in a bunker near the launching site.

d. Procurement and furnishing of two office rooms for the computing group, for administrative and briefing purposes, and for storage of equipment.

e. Erection of a large tent near the radar as a storeroom for tools and stores for the rawinsonde probes.

f. Procurement of a sufficient supply of hydrogen.

g. Installation of a field motor-fuel dump.

h. Preparatory conferences with Italian agencies concerning the procedure for the shots, the time of the first launching, assignment of the safety zone, period and procedure of countdown, assignment of the restricted areas, and assignment of personnel.

3. Main Body:

All other participants arrived in Decimomannu on 14 April by air or by the land-sea route. On the same day, all participants were moved to Capo San Lorenzo and assigned there to the preparatory quarters. Beginning 15 April, normal work proceeded after assignment of all participants to the individual groups.

The few days remaining until the first scheduled rocket launch on 20 April were used for the erection, installation, maintenance, and testing of the equipment, and adjustment of the launcher and MSQ-1A radar. Further, the precise schedule of shots was drawn up to begin on 20 April. Thanks to the unflagging efforts of the participants, the first rocket was launched on schedule on 20 April after a previous, carefully practiced dry run.

4. Schedule of Shots and Safety Zone:

On application, the missile range headquarters approved the times for start of countdown and launch, which must be met absolutely.

In contrast to the schedule originally submitted in Rome, it was possible to obtain approval for launches only in the morning between 1030 and 1230 CET and in the afternoon between 1500 and 1800 CET, even after repeated meetings with the Italian Poligono officers. During these times, marine and air traffic is informed of scheduled shots in the safety zone (see fig. 1). The safety zone was determined in keeping with the Arcas rocket and its specifications. Therefore, the distribution of the launch times as uniformly as possible over the day and night to study the diurnal variation of the wind could not be carried out as projected.

In spite of this, the optimum possible distribution of the individual rocket launches over the day was obtained by scheduling the launches for three rockets per day at 1130, 1500, and 1750 CET, respectively (see daily schedule, table 1).

An obstacle to the determination of a precise schedule of shots, and especially to its punctual maintenance, was the fact that a further schedule of shots by a German test section with two Seacat rockets daily had to be carried out. In spite of difficulties, an appropriate coordination was achieved; the difficulties resulted mainly from the different length of the periods of preparation for launch (restricted safety zone). In the planning of future experiments, only one project should be foreseen for any period, in the interest of smooth implementation. The strict safety regulations and safety times lead almost inevitably to unnecessary lost time and mutual obstruction.

5. Equipment and Operational Groups:

The implementation of the experiments required the assignment of a number of operational groups with special functions.

The maintenance and preparation of the rocket materiel and launch installation and the execution of the launch itself were the responsibility of the launcher group (Dipl.-Ing. W. Liess as chief, Ing. J. Schwarz, Mr. Witzke, Mr. S. Buhl, and Mr. A. Finkenzeller).

The supervision of the safety of the land and sea area, the examination and approval of the launch specifications, and the launch clearance were provided by the Italian safety headquarters at the Poligono in Perdas de Fogu. The interests of the German experiment group were represented by a liaison spokesman assigned to Perdas de Fogu in each case. This function required special tact and negotiating skill, to achieve an optimum in opportunities for measurement. It was performed by Dr. W. Attmannspacher, unless detained by consultative and analyis obligations.

The computing group (Ing. J. Lidl, Mr. Jost, and Mr. Ebertseder) had the task of procuring the meteorological data for the rocket launch, constantly computing the launcher angle to be used, and communicating these items to the launch control center. After a successful launch, the computing group undertook the collection and compilation of all data and a preliminary analysis if possible.

The radar group (Mr. Le May, Ing. Branns, Mr. Riess, Mr. Happach, Mr. Wégé, and the generator servicemen, Mr. Grossmann and Mr. Renner) operated the MSQ-1A radar during the preliminary wind measurements with standard balloon targets and during the ROBIN measurements.

The launch control center was responsible for the progress of the experiment (countdown) and for coordination of all operations. The operational schedule for a normal day of shots is shown in table 1.

5.1. The Arcas Model 1 rocket with ROBIN nose cone is a sounding rocket with solid-fuel propulsion, a diameter of 11.4 cm, an overall length of 204 cm, and a total weight of 38.5 kg (see fig. 2). The rocket is stabilized in flight by a rigid four-fin tail assembly. The fins are slightly offset to give the rocket a slight spin around its longitudinal axis. The propellant has an average combustion time of 28 sec. After a further 100 sec, the nose cone is separated from the spent rocket motor shell by a small pyrotechnic ejection charge, and the folded ROBIN balloon is released at the same time. As the balloon is released, a capsule containing isopentane opens inside it. The isopentane evaporates, and its vapor pressure immediately inflates the balloon and simultaneously unfolds the mylar radar reflector (octahedron) in the balloon. The balloon with gas capsule and radar reflector weighs 122.8 g and has an essentially constant diameter (of plastic material) of 1 m (±0.5% per 10 mb).

Errors in production and assembly, especially in inserting the solid propellant, may lead to a nonuniform combustion of the propellant, causing an excessive generation of gas inside the propulsive charge and along the outer surface and an explosion of the rocket (abort).

The Arcas rocket is launched from a standard launcher (see fig. 3). The launcher consists primarily of the launch tube, the pressure tank, an azimuth table, and a carriage that permits traverse of the launch tube from 0° to 90° in the vertical and 360° in the horizontal. Appropriate circles for azimuth and elevation are provided. The accuracy of the adjustments (±0.5°) is sufficient. The entire launcher has to be mounted on a base plate and, after precise leveling, firmly anchored. The pressure tank of the launcher contains what is called a gas generator, which imparts additional acceleration to the rocket after electrical ignition during the launch. A prescribed and thoroughly rehearsed procedure was followed in preparing the rocket, loading, setting the launcher, ignition check, and ignition.

5.2. The MSQ-1A radar. The MSQ-1A radar was set up about 700 m from the launcher. The radar was situated and leveled with the help of Italian theodolite stations.

Table 1

Daily Launch and Maintenance Schedule, Sardinia, 1964

Preliminary operations: 0730-0900 CET

Maintenance, inspection, and repair work on the launcher and radar.
Preparation of rockets and fuses in the rocket bunker.

Instruction and further training of participants in the individual measurement and handling tasks.

First launch:

Start rawinsonde	0900	finished by	1015
Special Italian pibal	0930	finished by	1010
Countdown start			1100
Launcher angle ready		by	1115
Fire (t = 0)			1130

1200: Lunch

Second Launch:

Start rawinsonde	1230	finished by	1330
Special pibal	1300	finished by	1340
Countdown start			1430
Launcher angle ready		by	1445
Fire (t = 0)			1500

Third launch:

Start rawinsonde	1540	finished by	1650
Special pibal	1600	finished by	1640
Countdown start		about	1720
Launcher angle ready		by	1730
Fire (t = 0)			1750

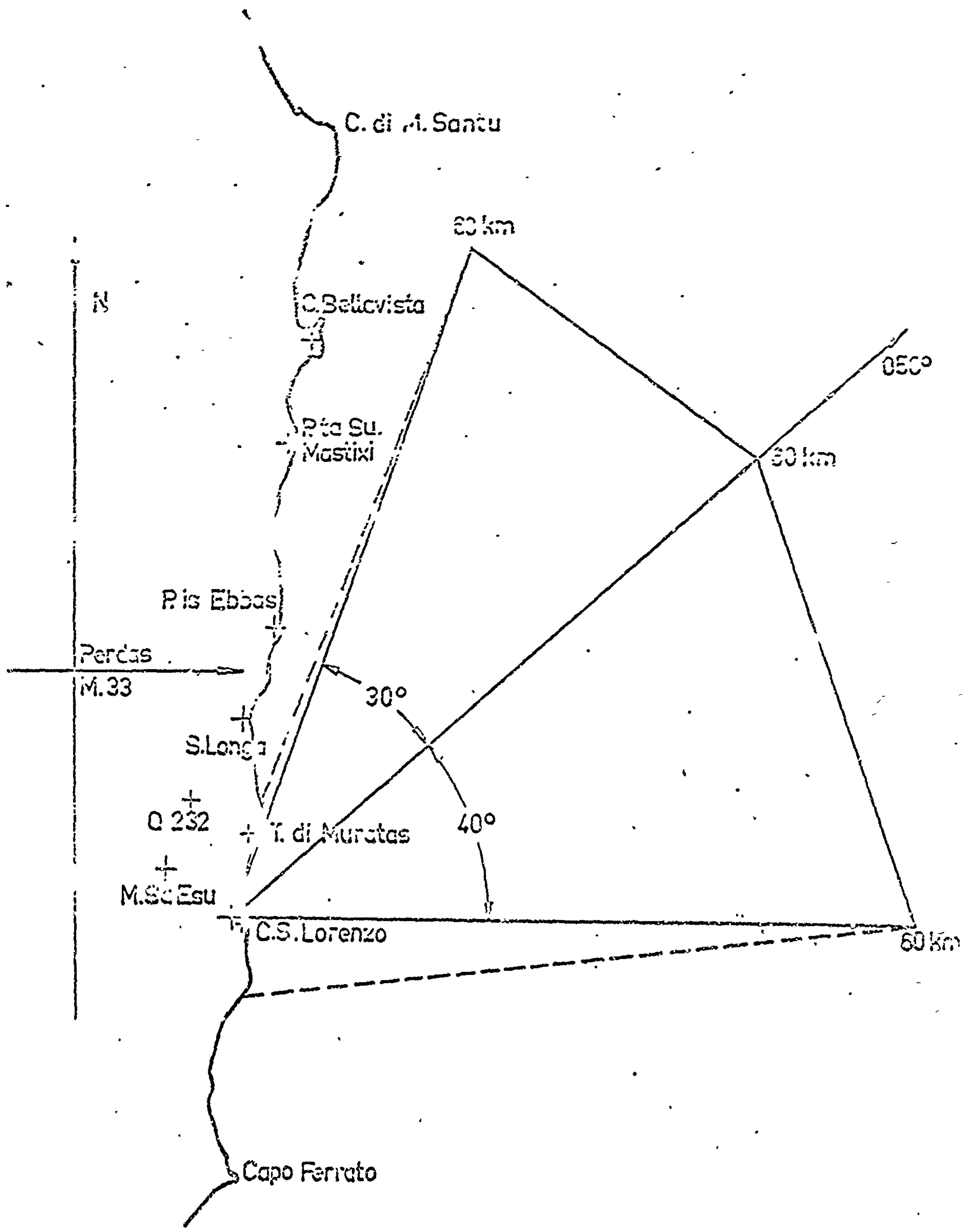


Figure 1. Principal firing direction and safety zone at the Salto di Quirra range.

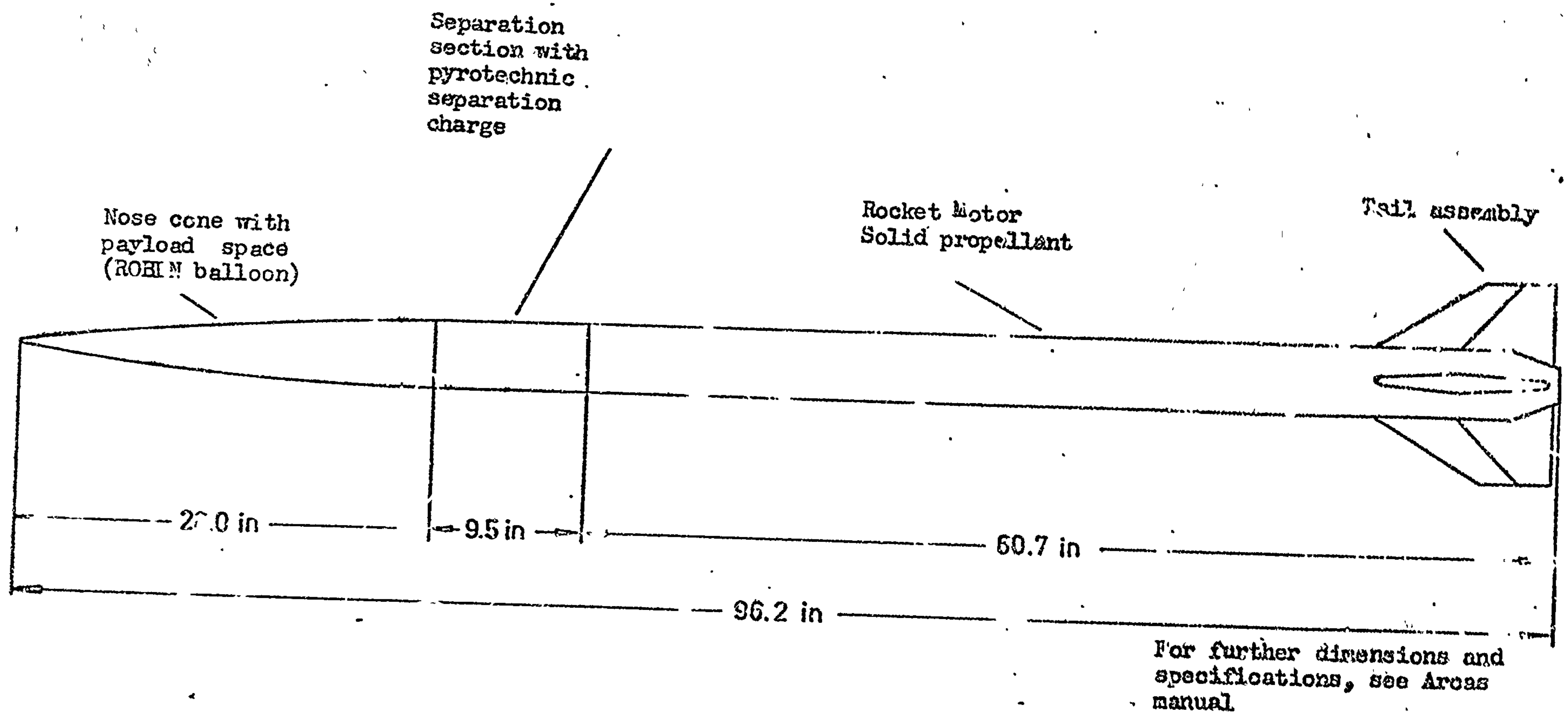


Figure 2. The Arcas Model 1 ROBIN rocketsonde

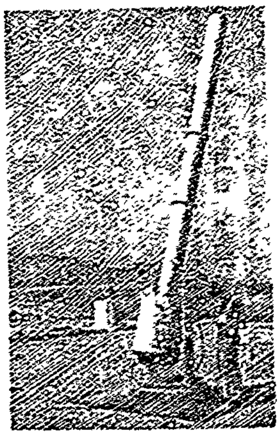


Figure 3. a. Launcher b. Launcher with rocket just launched.

The MSQ-1A (see fig. 4) is equipped with a parabolic dish 2.4 m in diameter and has a maximum range of about 340 km and average range slightly less than 100 km at a wavelength of 10 cm and output power of about 500 w with a target having a backscattering cross section of 1 m^2. The half-width of the transmission lobe is 3°. The manufacturer states the accuracy as ± 1 mark, corresponding to 5×10^{-2} deg for both elevation and azimuth. At a range of 70 km, this corresponds to a distance of ± 60 m (about 8/10,000 of the range). While the possible error in the tangential direction results from the inaccuracy of the angular determination and angular adjustment, the maximum error in the radial direction is due to the pulse width of the radar. With a pulse width of 0.8 μsec, the radial error will be ± 120 m nearly independent of the range, as long as the strength of the received signal is sufficient for an effective response of the radar.

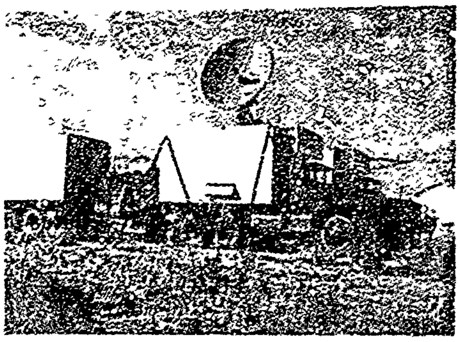


Figure 4. The MSQ-1A radar in operation.

The maximum possible errors in the wind measurement can be deduced theoretically from the abovementioned instrument errors. They are inversely proportional to the time interval between individual measurements. However, the wind exhibits a considerable time and space structure whose determination is the purpose of the measurement. Therefore, the time intervals between any two determinations of the position of the target must not be unduly prolonged. For the average ranges in these experiments and a time difference of 1 min between the individual observations, the possible maximum error of the mean wind speed as determined from minute to minute is ±1 m/sec. This error could be exceeded if the radar no longer had the aforementioned instrumental accuracy, due to wear and tear or inadequate maintenance. However, an assessment of this possible source of error can be deduced from an examination of the records obtained. If this source had given rise to an unnoticed inaccuracy, it would have shown up in a lack of reproducibility of the setting for the same target and in a temporary discontinuity in the record. However, no such effects were detected, despite careful observation. Therefore, it can be assumed that the abovementioned accuracy was attained in practice.

A further indication of the accuracy attained arises from a comparison between the resulting data and the records of the Italian RIS radars. No appreciable difference was established on any of the soundings; hence, no deficient functioning of the MSQ-1A radar can be deduced. In general, the range of the ROBIN balloon from the radar antenna was between 70 and 100 km, and often less than 50 km, which provides assurance that the accuracy of the measurements attains the aforementioned value, on the average.

The radar is connected to an analog computer and a trajectory recorder, which permits tracing the path of the ROBIN balloon in horizontal projection on different scales. Recorders also continuously register the azimuth, the elevation, the horizontal and slant range, and the height.

As already mentioned, two permanently installed Italian radars of the Selenia RIS-1C type participated in tracking the ROBIN targets, in addition to the radar of the German group. In individual cases where the location favored one of these spaced radars, it acquired the target before the German team did. In these cases, the angle and range data were exchanged immediately by all the participating groups, so that practically no time was lost. In the final evaluation, for which the complete records of the Italian radars were available, it was found that the accuracy of the latter did not exceed that of the MSQ-1A in any case. However, the records of the Italian radars provide a welcome check on our own measurements, though no improvement of the results. Systematic differences between the measurements by the Italian radars and the MSQ-1A could not be found. The detectable differences fall within the instrument errors of the two types of radars.

5.3. The computing group. First of all, the tasks of the computing group included the procurement of meteorological records from the Italian civilian and military weather services, e.g., weather forecasts, aerological reports of the Elmas and Alghero stations, pibal wind measurements up to 2000 m in vertical cross section in collaboration with Italian military personnel, continuous observation of the surface wind as measured at two prominent points near the launcher, and communication of these data to the chief of launch operations during countdown. Further, the computing group was responsible for analysis of the wind values recorded with the MSQ-1A radar in conjunction with a balloon target at heights up to 20 km before each launch. A further essential assignment was to determine the wind influence (wind weighting) on the upward path of the rocket and to compute the launcher angles for azimuth and elevation by a prescribed procedure (iteration method; see Arcas manual) that was improved and rationalized in some respects by the computing group. If there was no wind up to a height of 20 km, the "zero" azimuth was 50° and the "zero" elevation was 86°. The corrections were computed for these angles. Then, the plotted families of trajectory curves could be used to predetermine the apogee and the impact point. Due to wind variations during the wind computing period and countdown (about 100 min), there often were differences between the computed and actual apogees and impact points. The prediction of the apogee was needed in order to give the radars directions for rapid acquisition of the target, since the ROBIN balloon with reflector was ejected from the nose cone at apogee or shortly after (see fig. 5). Tracking of the upward path by the radars was impossible, due to the excessive required tracking speed of the radar dish and the inadequate back--scattering cross section of the rocket itself.

After the launch and successful tracking of the target, the computing group undertook the collection and comparison of all measurement data, and if possible, a preliminary analysis of the individual probes.

A survey of the preliminary analysis has been published by Dr. Attmannspacher in a Report of the German Weather Service.

5.4. <u>The countdown</u>. The launcher with associated safety bunker and observation post (about 100 m from the launcher), the computing group, the MSQ-1A radar, the Italian RIS-1C radars, the launch control and supervision center (chief of launch operations), and the Poligono in Perdas de Fogu were in direct communication with one another by voice radio or by telephone systems. Also, the countdown times were known to all stations, either by synchronized clock or by loudspeaker. Both control and counting of the countdown were carried out in accord with a stipulated procedure by the Italian Poligono headquarters in Perdas de Fogu with the respective instructions and commands to

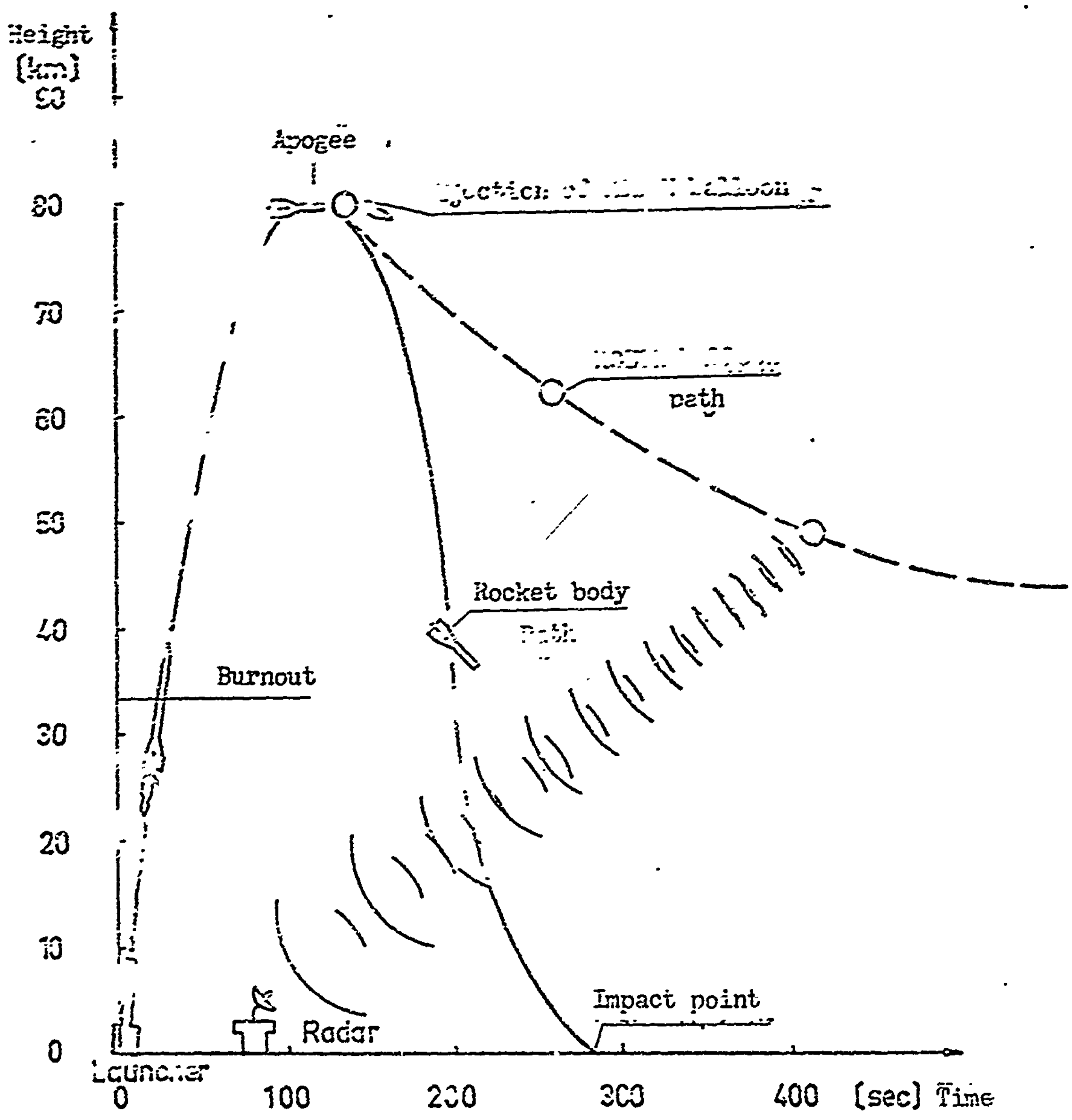


Figure 5. Diagram of rocket and ROBIN balloon paths

the individual operational groups. As a rule, the countdown time was 30 min. Irregularities in the rocket and launcher preparation or the presence of vessels, aircraft, vehicles, and unauthorized persons in the safety zone caused an immediate stop of the countdown until the cause was determined and removed. For example, the presence of vessels in the safety zone (sea) sometimes caused periods of interruption longer than 60 min. Also, a great increase in the surface wind (more than 10 m/sec) frequently interrupted the countdown, which in two cases was suspended and postponed to a later time (see table 2, actual times of launch in comparison with table 1, scheduled times).

The Arcas supplier stipulates that no guarantee can be assumed for the precalculated trajectory of the rocket if the surface wind is greater than 10 m/sec. Therefore, the Poligono prohibited the launch if the surface wind was greater than 10 m/sec. The chronological schedule of the countdown to the time t = 0, when the rocket is ignited by the launcher personnel, is reproduced in table 3 in its original form.

The rigorously restricted safety zone around the launcher could be entered again by authorized personnel 5 min after a safe launch. There was only one abort out of the 45 launches implemented (2%). Figure 6 gives a summary of the times of acquisition of the ROBIN balloon after t = +130 sec, i.e., about 2 min after starting time, by the MSQ-1A radar, the starting time being the time of ejection of the ROBIN balloon from the nose cone. For the reasons already mentioned, the acquisition times for the RIS-1C radars differ only little from those of the MSQ-1A. Probes for which the acquisition time is more than 4 min (see fig. 6) can only be accounted for by a failure of the ROBIN balloon to unfold satisfactorily after ejection at apogee because the gas capsule did not inflate it to a spherical shape. As a result, the target did not have the full reflecting effect, hence produced an extremely poor or unrecognizable echo in the radar. In two probes with long acquisition time, the ROBIN balloon was located by telescope after a rather long radar tracking period with a wind direction that made the balloon drift toward the radar. It was found that the ROBIN balloon had been deformed into a flat disc, which explains the poor echo in the radar. It is natural to suspect that the same effect occurred in all shots where the target was not acquired, although the rocket obviously had functioned satisfactorily.

Out of a total of 45 rocket launches, 33 ROBIN balloons were acquired (73%) and qualified for analysis. Eleven ROBIN balloons (25%) were not acquired; one Arcas rocket (2%) exploded shortly after launch (abort) at a height of about 400 m.

5.5. Dismantling and return transport. The dismantling of the MSQ-1A radar, the launcher, and the entire experimental equipment was begun on 9 May 1964. All the equipment and stores had to be packed, some of it for shipment by water. The return transport was again routed via the German AF Training Detachment in Decimomannu. From there, all cases and small items were routed by military transport aircraft and all vehicles by sea to their respective destinations. The return trip of the personnel was either by air or by the land-sea route. The only items left behind in Sardinia were 35 Arcas rocket motors and 15 ROBIN nose cones. They are located in an ammunition bunker of the German AF Training Detachment in Decimomannu under its supervision. The last return transports, hence the entire experimental operation, ended on 15 May 1964.

Table 2

Launch Times, Launch Number, and Date, Sardinia, 1964

Date	Launch No.	Launch Time
20 April	1, 2,	(1615) (1707)
21 April	3, 4, 5,	1032 (1528) 1706
22 April	6, 7, 8.	1159, 1503, 1733
23 April	9, 10, 11, 12,	1138 (1503) 1524, 1723
24 April	13, 14,	1102, 1504
27 April	15, 16, 17,	1220, 1502, 1748
28 April	18, 19, 20, 21, 22,	1128, 1200, 1503, 1659, 1746
29 April	23, 24, 25,	1142, 1508, (1734)
30 April	26, 27, 28,	1229, 1527, 1719
4 May	29, 30, 31, 32, 33,	1145, 1209, 1517, 1743, 2243
5 May	34, 35, 36, 37,	(1209) 1229 (1735) (1800)
6 May	38, 39, 40,	1220, 1500, 1722
8 May	41, 42, 43, 44, 45	(1139) 1203 (1522) 1548, 1747

Parentheses indicate target not acquired.

General Countdown

Announces	Operations	Respons	Comunications & Notes
-30' Count Down starting	Start of C.D. operations. Init. wind check.	ALL COMs	COMs-COS-COMi confirm to own representative at COM
-29' Report of instrumentation	Report of readiness of ground instrument.	ALL	Reports to representatives at COM. Yellow lamps COMi & COM
-28'	Report on wind cond. Decision to launch.	COMs COM	
-26' Launching area clear	Clear area of unnecessary personnel.	COMs COS	COS confirms to COM
-25'	Launcher and gas generator loading.	COMs	
-16'	Launcher and gas generator ready.	COMs	COMs confirms to COM
-15'	Wind condition and confirm. To launch	COMs	Decision between COM and COMs
-14' Launching area safe	Only armers near the launcher	COMs COS	COS confirms to COM
-13' Igniter installation	Igniter installation and connection	COMs	
-10'	Launcher setting data	COMs	Data from COMs to armers and to COM
- 8' Launcher setting	Launcher setting operation	COMs	
- 6' Final arming	Final arming connection	COMs	
-5' Launching area free	Launching area completely evacuated	COMs COS	Green lamp form COS officer S. Lorenzo to COS director
- 4'	Igniter continuity check. Firing connect.	COMs	COMs confirms to COM
-3'	Ground wind data and launcher setting check	COMs COM	Launch data to COM and final decision
- 2'	Launch data to ground instrumentation	COMs COM	COMs to COM and COM gives data to COMi
-60" 60 seconds to launch	Instrumentation and launcher ready	COMi COMs	COMi and COMs green lamps to COM
-50"	Ground wind check range safety ready	COMs COS	Wind data to COM COS green lamp to COM
-30".25".20".15"	Count each 5 seconds firing consent	COM	Firing consent from COM to COMs
-10"..6"..5"..4"	Count each second firing key engaged	COM COMs	
-3"..2"..1"	Firing switch safety removed	COMs	
± 0 : Fire	Firing switch closed	COM COMs	
+1"..9".16".20"	Count each second	COM	
+30".40".60"	Count each 10 seconds, ground wind check	COM COMs	At +28" end of combustion
+80".100".260"	Count each 20 seconds	COM	At +128" separation of parachute

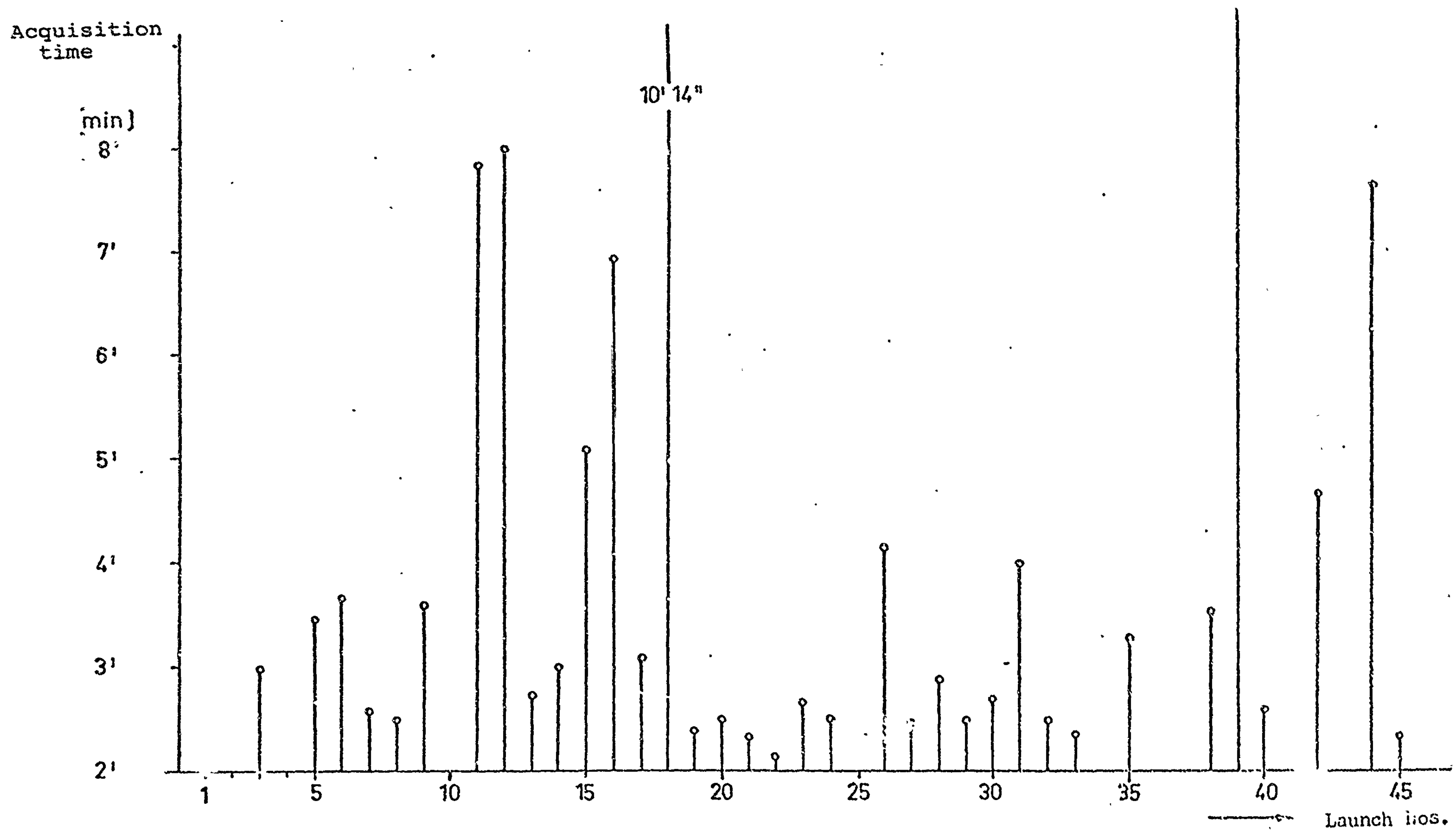


Figure 6. Statistical distribution of the acquisition times after t = 130 sec; rocket probes, Sardinia, 1964

III. Analysis of the Data

1. General Weather Situation

In the period from 21 to 23 April 1964, the large-scale circulation is characterized by a low over the British Isles extending to the 100-mb level and having a nearly vertical axis. Over the European mainland, there is a blocking high that extends from the Balkans to Finland. Consequently, the zonal flow of upper air from the eastern Atlantic to the western Mediterranean is changing into a meridional north-to-south flow.

The eastward movement and weakening of the eastern European upper-air high-pressure wedge, which begins on 23 April, moves the thick low-pressure system of the preceding days from England toward the east without much change, and on 24 April its center is over the North Sea. However, the leading edge of a central Atlantic low is causing a rise in pressure over western Europe and the eastern Atlantic, and a ridge from the Azores high extends to Iceland. In the upper atmosphere, this ridge connects with a high in the area of Iceland and southern Greenland. The result is a northwestern upper-air flow over southwestern Europe in the troposphere and lower stratosphere.

During the subsequent days, the western European surface high moves farther toward the mainland. At the same time, the upper-air wedge extending from Spain to the Arctic turns toward the east. The tropospheric Black Sea/Balkan low extends up to the tropopause as a steering center; hence a meridional orientation of the isohypses begins by 28 April throughout the troposphere over southern Europe. In part, the winds aloft veer past north through a trough-like extension of the upper-air Black Sea low to western North Africa.

In the period from 29 through 30 April, the upper-air European ridge moves with the general western drift to Russia, and an upper-air western flow begins to predominate over all of Europe.

On 4 May, a powerful west-to-east flow has set in over the eastern North Atlantic between the Azores high and a steering North Atlantic low-pressure system, and on 5 May it extends from eastern Canada to the Black Sea. Throughout the troposphere, it is associated with large meridional temperature differences and rather high wind speeds. During the subsequent days, the North Atlantic low-pressure system changes little in position and intensity and remains the principal steering center. The upper-air trough over the western Atlantic on 6 May, which communicates with this center, turns eastward; on 7 May it is over the central Atlantic and on 8 May, over England. Its leading edge causes advection of warm air as far as central Europe, which leads to the formation and subsequent reinforcement of an upper-air ridge extending from Morocco to Scandinavia.

Throughout the reporting period, from 21 April to 8 May 1964, the pressure distribution at the levels of 50, 30, 20, and 10 mb (about 20 to 31 km above the surface) is characterized by small gradients.

2. Summary of Wind Measurements:

At the German Aerospace Research Establishment in Munich-Riem, the extensive records of measurement data were examined, the individual values extracted, tables compiled, and corresponding graphs and measurement-system conversions drawn up.

Figure 7 gives a summary of all rocket probes and the final heights of the analysis.

The individual wind data (speed and direction) were taken from the trajectory record (horizontal projection) as time averages for every 30 sec. The height values and the check on the azimuth and slant-range values were taken from the strip charts of the radar computer. A reading accuracy within ±50 m was provided by the individual records. This accuracy is in agreement with the technical capabilities of the equipment. The recorded wind data were used to prepare a vector graph for all 45 rocket probes in height steps of 2 km for a quick synopsis of the entire measurement program (figs. 8 and 9).

The individual wind measurements from 0 to about 20 km above ground are shown with the corresponding rocket measurements. As a rule, they were begun about 90 min before launch and made with a radiosonde. Probably, the discontinuities between adjacent rawinsonde and ROBIN balloon (rocket) measurements are due to the difference (up to 90 min) in times of measurement. However, figs. 8 and 9 indicate a good agreement in most cases.

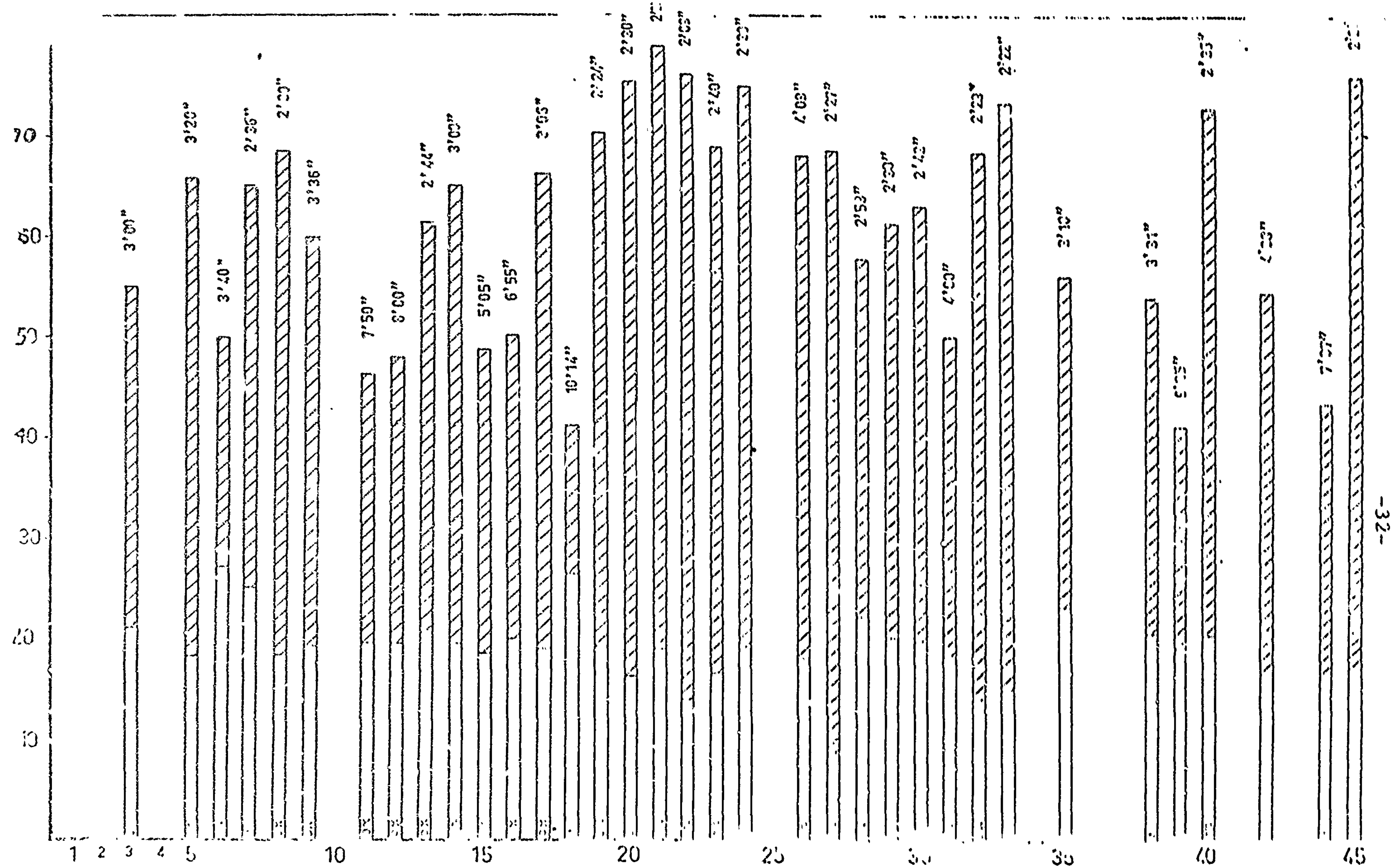


Figure 7. Maximum heights, terminal heights of analysis, acquisition time, and type of radar employed for 45 rocket probes, Sardinia, 20 April to 8 May 1964. Empty spaces indicate no target acquired by radar.

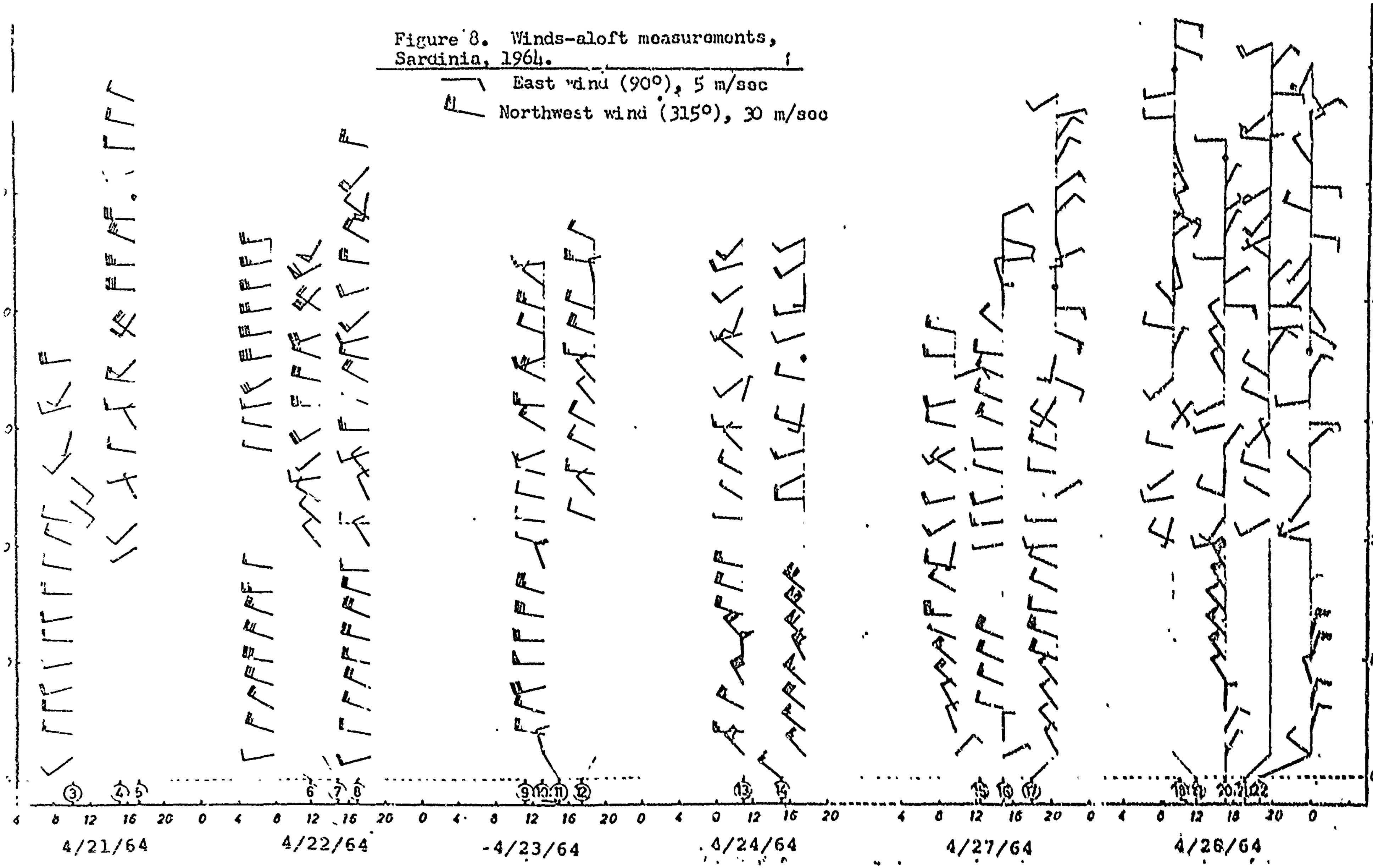
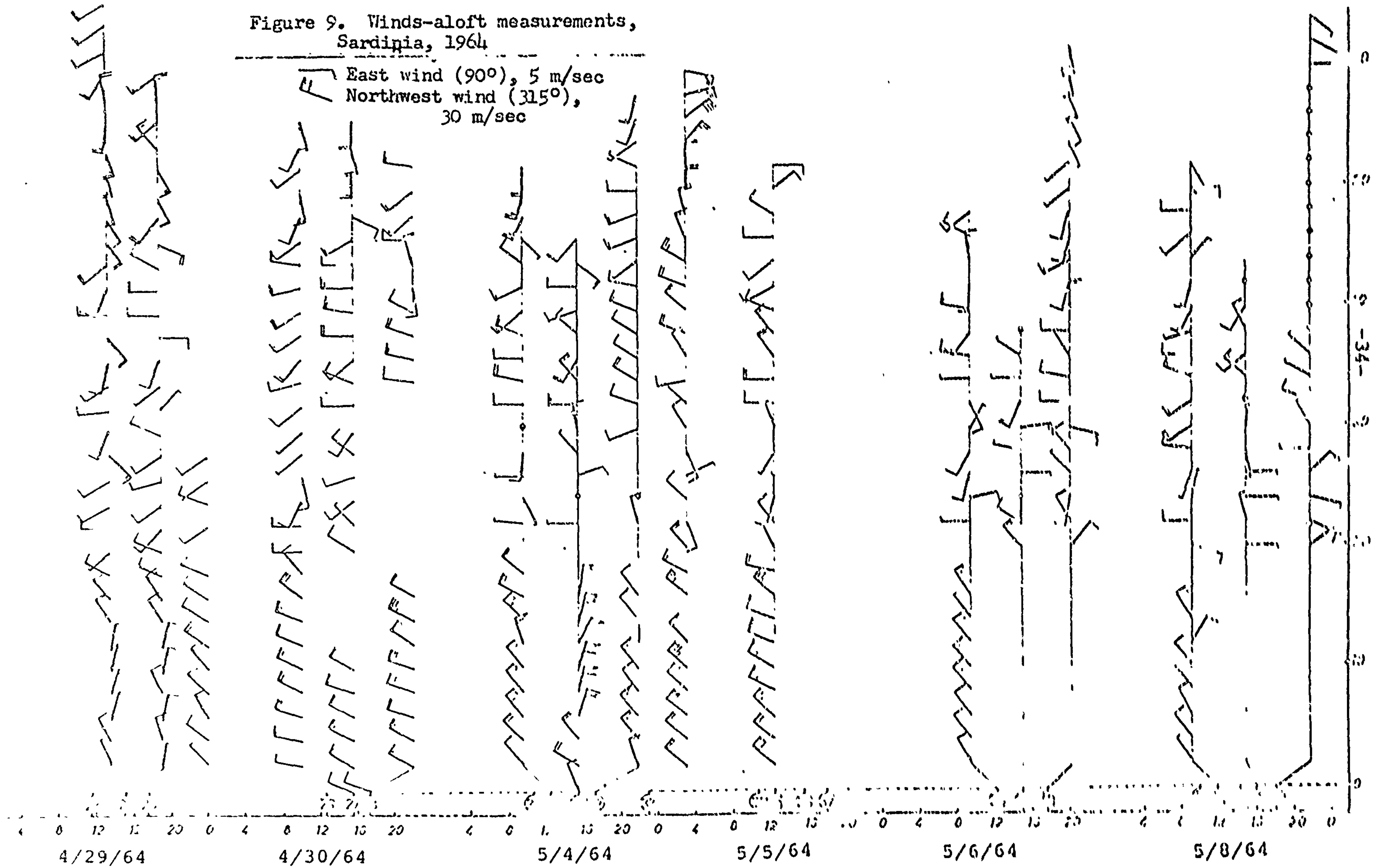


Figure 8. Winds-aloft measurements, Sardinia, 1964.

East wind (90°), 5 m/sec

Northwest wind (315°), 30 m/sec

Figure 9. Winds-aloft measurements, Sardinia, 1964



The wind data obtained over Sardinia in the troposphere and in the part of the stratosphere accessible to the sounding balloons correspond to the weather situation described on pp. 30-31. From 21 to 24 April, the wind veers and increases in speed. On 24 April at a height of 12 km, it is north-northwesterly at 32 m/sec. On 27 April, the wind backs and decreases, but veers to northerly again on 28 April. Beginning 30 April, the wind in the troposphere and lower stratosphere is blowing hard from the northwest. It does not slacken appreciably until the last day of measurements (8 May).

During the first few days of the experiments, the wind in the stratosphere at heights above 20 km is a moderate westerly. Beginning 23 April, the wind speed decreases considerably, and on 28 and 29 April, there is a near calm aloft. On 30 April and 4 May, a freshening of the winter westerly is observed once more. From 5 May on, the air is calm up to great heights.

At the greatest accessible heights above 50 km, the backing of the wind from west to south to east is more pronounced, but the number of measurements is probably too small to establish a time between 30 April and 4 May as the characteristic time of the wind shift. In any case, it seems safe to infer a heating of the upper stratosphere and mesosphere in the northern part of the experimental area from the variation of the wind.

The measurement period was chosen such that according to U. S. experience (cf., e.g., W. L. Webb, Astronautics and Aeronautics, March 1964), one could expect the "normal " shift of the wind aloft in the upper stratosphere from westerly to easterly during the period of experiments. Although this behavior of the wind aloft is implied by the data obtained, it is not explicitly demonstrated. Whereas west winds predominate at all heights as the period of experiments begins, the east wind had come to prevail only partially and only at the greatest heights of the measurements at the end of the experimental period. Perhaps a prolongation of the period of measurements would have shown a clear pattern. Of course, one cannot preclude the possibility that the time of the wind shift is slightly different in southern Europe than in America. Only further measurements can indicate a decision in this respect. Table 4 gives a synopsis of the mean values of wind speed and direction for all completed probes.

3. Wind Components:

The wind components for the individual probes (westerly, +; easterly, -; northerly, -; southerly, +) were computed and arranged in tables (see appendix). Figure 10 gives the mean profiles averaged over the entire period of measurements.

On the average, the westerly component predominates from a height of 20 km(2.4 m/sec) to 48 km. It has a broad maximum of about 5 m/sec at heights between 32 and 46 km, but above this it

Table 4

Wind Speed and Direction Averaged over All Measurements
from 21 April to 8 May 1964 in Sardinia

Height km	No. of Measurements	Mean wind speed m/sec	Wind direction
20	21	2.9	304°
22	29	2.9	260°
24	31	2.3	249°
26	30	2.1	264°
28	30	2.9	251°
30	30	3.4	288°
32	30	4.7	267°
34	31	6.0	284°
36	31	5.5	277°
38	30	5.3	280°
40	28	3.9	261°
42	28	4.7	245°
44	27	5.7	253°
46	26	3.9	247°
48	23	2.5	227°
50	20	3.4	196°
52	20	2.9	206°
54	16	2.0	243°
56	13	2.9	172°
58	10	3.0	168°
60	8	4.5	162°
62	(5)	(5.9)	(208°)
64	(3)	(2.3)	(197°)
66	(2)	(3.5)	(187°)

decreases markedly, and at 56 km it becomes easterly. The north-south component fluctuates unindicatively around zero up to 40 km. Above 40 km, the southerly component increases. At a low scalar speed, the wind backs from WSW at 42 km to southerly at 56 km to south-southeasterly. Above 60 km, the evidence no longer suffices for a clear statement.

In order to provide a clearer impression of the seasonal shift in the prevailing winds, the total measurement period was divided into a number of phases. Figure 11 shows the mean profile of the east-west component for each phase. For technical reasons (the Italian personnel being unavailable at night and on weekends), the probes were distributed very inhomogeneously over the measurement period. Therefore, the number of probes is not equal in the partial means for the phases. If it were equalized, the weight of a time interval thoroughly covered by probes would be unduly great and that of a time interval with relatively few probes, too small. Hence, five subintervals characterized by similar prevailing winds were established and are illustrated in fig. 11. The straight vertical lines represent the overall mean of the east-west component of the wind at each height for the entire measurement period. The deviation of the subinterval mean from the overall mean is plotted as the abscissa for the subinterval identified at the top. The scale (in m/sec) is indicated below the graph for the first subinterval.

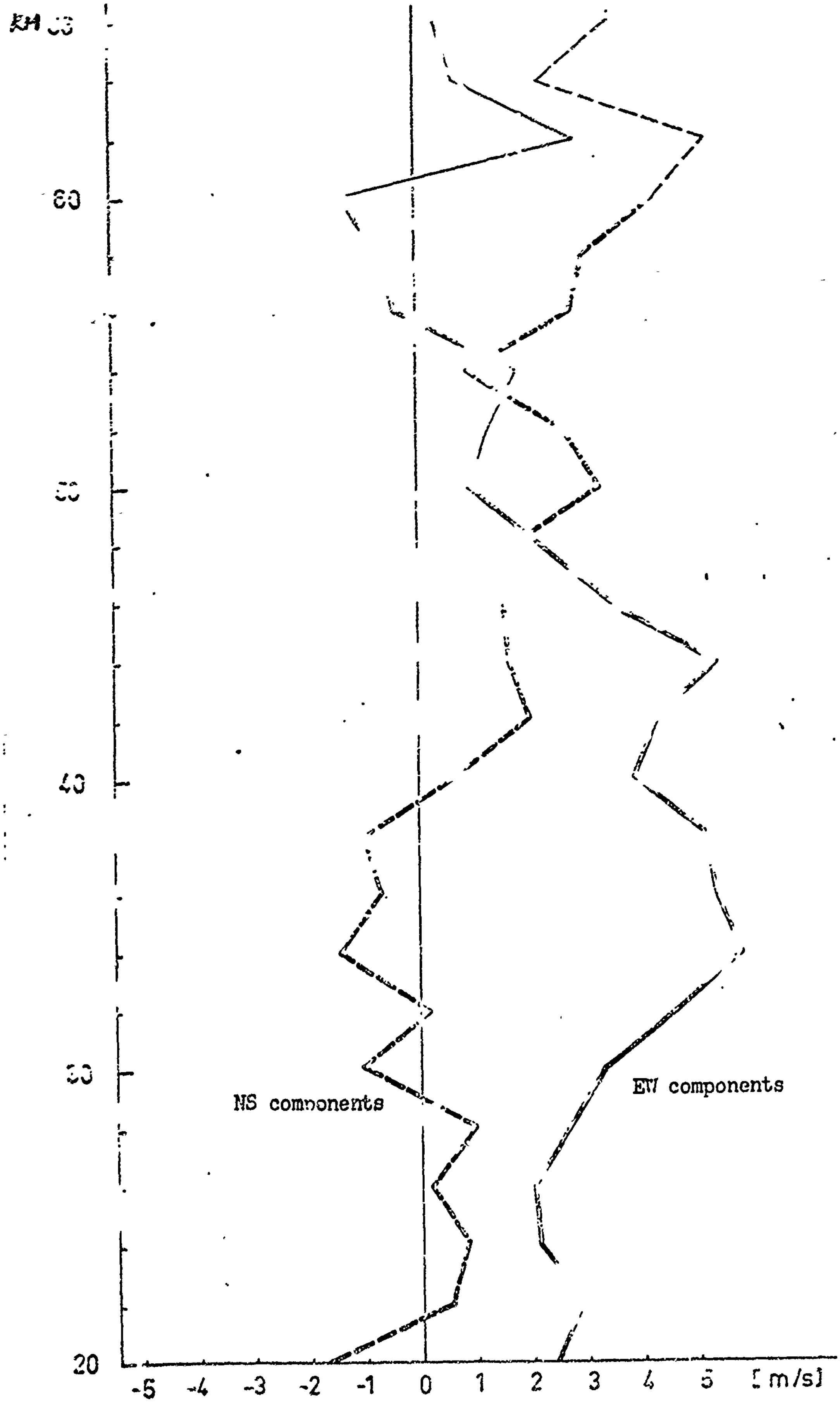


Figure 10. Mean values of the EW components and NS components of the wind between 20 and 70 km above the ground, averaged over all probes from 21 April to 8 May 1964

This representation characterizes the shift in the prevailing wind and clearly indicates that this shift from westerly to easterly does not occur all at once, but requires a period of about three weeks (which also calls for a prolonged period of measurements). No statement on details in this change (e.g., characteristic vertical cross section) can be made on the basis of the available data.

4. Variation of the Wind Vector with Height:

The need for an analysis based on 1-min averages of the wind leads to a smoothing of the instantaneous values of wind speed and direction. Only a very limited statement can be made about the variation of the wind with height (wind shear), in view of the accuracy of the radar. Therefore, one cannot make more accurate specifications of the variation of the wind vector than would correspond to the wind-speed data ± 1 m/sec, averaged over a measurement interval of 1 min.

To obtain at least a rough impression of the variation of the shear vector with height, the profiles of the wind components were statistically analyzed and segregated into broad classes. The result is shown in table 5.

Whereas about half of all the observations indicate wind shears below and above 4 m/sec per kilometer of difference in height, the values are larger in a considerable number of cases. The largest measured values were between 8 and 16 m/sec per kilometer of difference in height. In the EW component, such values occurred twice during the experimental period

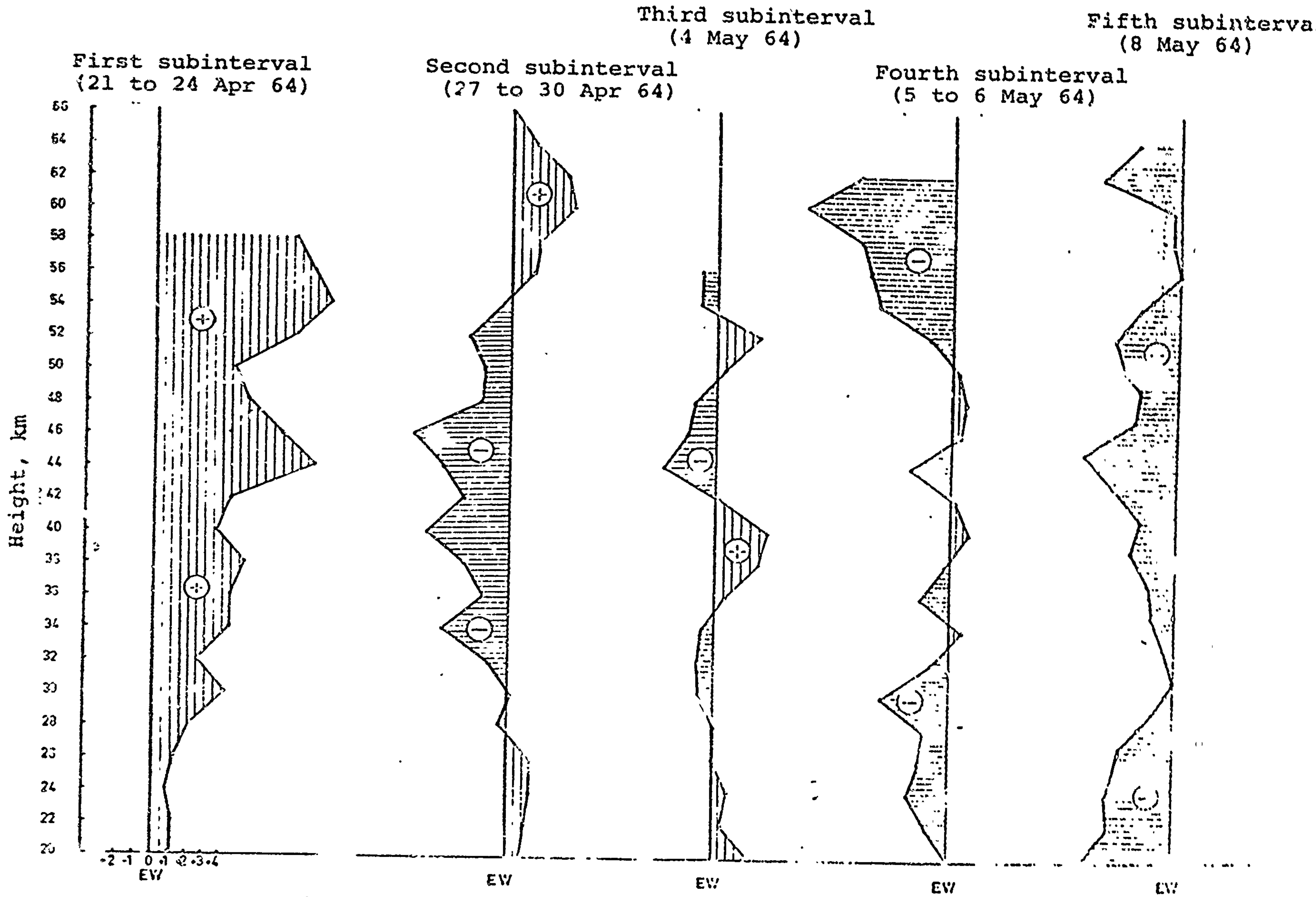


Figure 11. Scatter of EW wind components by consecutive subintervals of probes and by heights (subinterval average <u>versus</u> overall mean), Sardinia, 1964.

at heights between 40 and 46 km. The NS component produced four such observations between 36 and 48 km above the surface.

Table 5

Frequency (%) of Wind-Shear Values of the Wind Components as a Function of the Height

Height (No. of cases)	Wind Shear: Less than 1 m/sec per km of height, EW comp.	Less than 1 m/sec per km of height, NS comp.	between 1 and 4 m/sec per km of height, EW comp.	between 1 and 4 m/sec per km of height, NS comp.	greater than 4 m/sec per km of height, EW comp.	greater than 4 m/sec per km of height, NS comp.
20/30 km (170)	48 %	37 %	47%	58 %	5 %	5 %
32/42 km (174)	41 %	40 %	48 %	51 %	11 %	9 %
44/54 km (117)	52 %	50 %	37 %	44 %	11 %	6 %
56/66 km (28)	68 %	43 %	28 %	39 %	4 %	18 %

5. Time Variation of the Wind:

It was intended to investigate the short-term variation of the wind in addition to the seasonal change. Therefore, whenever the weather, supply, and safety situation permitted, rockets were launched consecutively at the shortest possible time intervals and their data were intercompared. Twenty pairs of successful rocket probes were selected from the total number of launches. The average time interval was 178 min between the two probes of a pair; the shortest interval between two shots was 47 min, and the longest interval included in the analysis was 394 min. First, these data were divided into two classes, which comprised ten pairs of probes with intervals less than 161 min and ten pairs with intervals more than 161 min. This was done to determine whether the differences in the measured wind conditions varied systematically as a function of the elapsed time between the two launches. No such systematic variation was found. No differences between subgroups with shorter and longer time intervals were established, except for the scatter to be expected in view of the small number of cases compared. Therefore, it seemed correct to treat the groups as a unit.

Table 6 shows the time variation of the wind components as a function of height, which was measured by 20 pairs of probes at an average time interval of 3 hr.

Table 6

Time Variation of the Wind Components for 3-hr Interval as a Function of Height

Height	Time variation per 3 hr m/sec		No. of data compared
	EW comp.	NS comp.	
20/30 km	2.42	2.89	99
30/40 km	2.87	3.53	107
40/50 km	3.33	4.78	72
50/56	4.64	5.89	24

Due to the different heights reached in the measurements to be compared, the number of available data pairs decreases rapidly with increasing height. Nonetheless, it is clearly evident that the NS component has a greater time variation than the EW component. Both components, hence the wind vector as a whole, show a clearly increasing time variability with increasing height.

6. Rate of Fall of the ROBIN Balloon:

As has already been stated, the fact that 25 % of the ROBIN balloons were not acquired by any of the radars implies that the inflation mechanism of these balloons had failed. Although it was supposed before the beginning of the study that it might be possible to use the rate of descent of these balloons to draw conclusions about the state of turbulence of the upper atmosphere, or even about its variation as a function of time of day or weather situation, this supposition had to be abandoned. Even if the target is acquired by the radar, it can by no means be expected that the balloon has a sufficiently regular shape to retain a well-defined velocity during a large part of its time of fall, or that a large number of balloons will behave somewhat uniformly. Table 7 shows five consecutive height intervals and the mean time of descent required by the balloons to fall through these intervals, the resulting rates of fall, and the number of cases included.

As a supplement to table 7, fig. 12 gives the distribution of the rates of fall for the individually tracked balloons. Although only a small number of balloons was acquired in the highest interval, the values for these balloons seem to have less scatter than for the lower intervals, where the times of fall differ by as much as 100%, despite the greater possible accuracy of the measurements.

Table 7

Height interval	No. of cases	Mean time of fall (min)	Mean rate of fall (m/sec)
240-220 kft	7	0.5	218
220-200 kft	13	0.6	182
200-180 kft	17	0.8	136
180-160 kft	25	1.2	91
160-140 kft	29	1.8	60

A more detailed analysis shows that the rapidly acquired targets, which reflect the radar beam well, do not sink particularly slowly in the low height intervals, but belong to the principal group with relatively high rate of fall. This implies that these balloons are the ones for which the inflation and the unfolding of the triple reflector functioned satisfactorily, while the inflation was unsatisfactory in the other cases. Presumably, the latter fell rapidly at first and were acquired late for that reason and because of the insufficient unfolding of the triple reflector. On the rest of its path, the balloon (whose shape was irregular due to unsatisfactory inflation) assumed an attitude with respect to the flow such that its resistance was maximum, and it sank much more slowly than a satisfactorily inflated balloon.

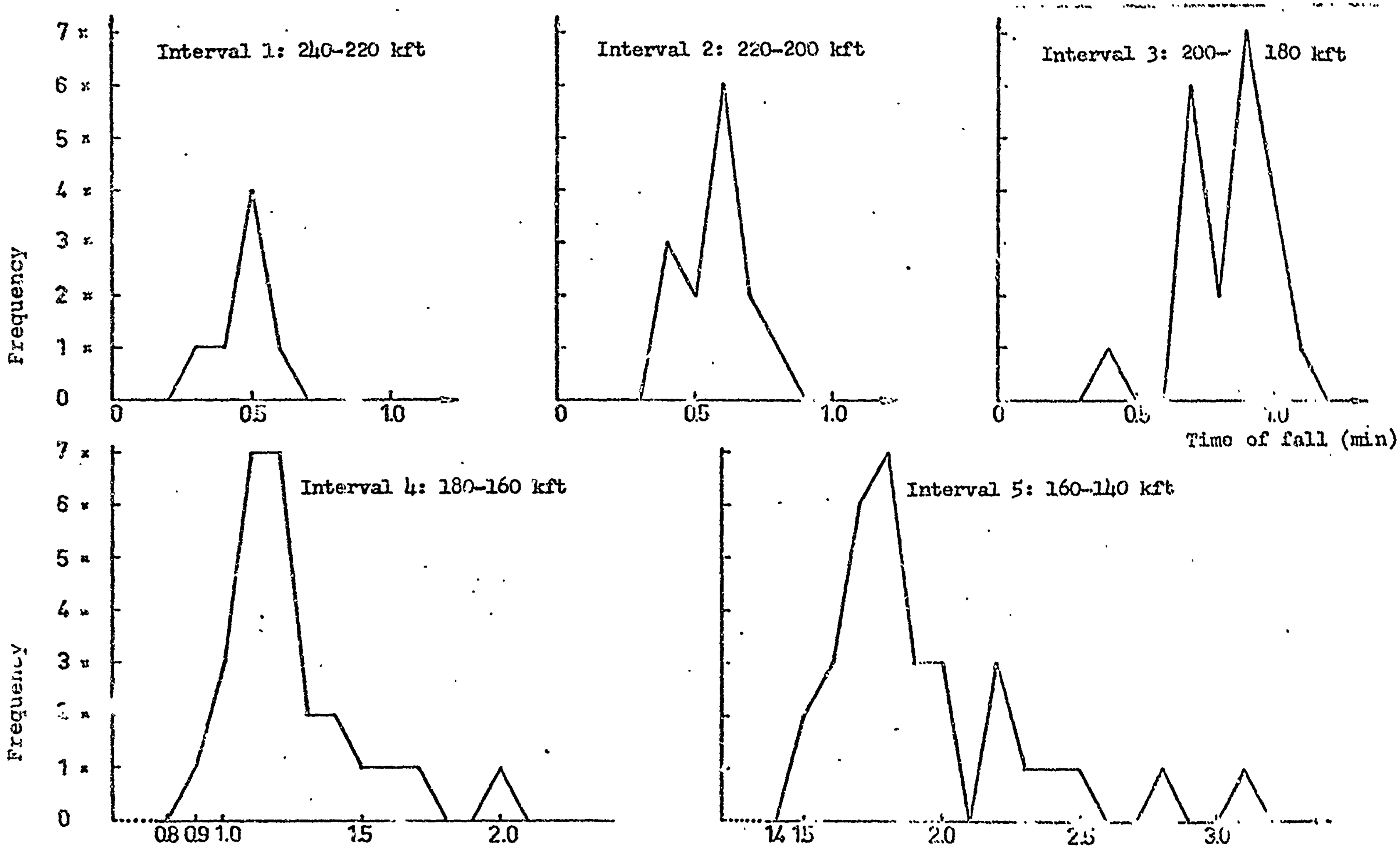


Figure 12. Frequency distribution of the times of fall for the five highest intervals (of 20 kft each); rocket shots in Sardinia, 1964.

7. Summary:

7.1. Winds-aloft measurements were made over a period of 14 days with three to four rocket probes daily, and the corresponding wind profiles were prepared.

7.2. The wind-speed data are in agreement with those of various authors in other countries (especially the U. S.) A comparison of the individual results with those of the other authors was not undertaken in the present paper.

7.3. The shift of the prevailing wind from the winter westerly to the summer easterly was detected and established partially.

A conclusive assessment can only be drawn up on the basis of a chronologically longer period of measurements.

7.4. The Arcas ROBIN rocketsonde is very suitable for determination of the wind up to a height of 75 km.

Appendix

Tables of the EW and NS Wind Components

(pp. 49-56)

EW and NS Wind Components in Rocket Probes, Sardinia, 1964

Ht (km)	Launch No., date, and launch time No. 3 (4/21) 1032		No. 5 (4/21) 1706		No. 7 (4/22) 1503		No. 8 (4/22) 1733	
	EW (m/s)	NS (m/s)	EW (m/s)	NS (m/s)	EW (m/s)	NS (m/s)	EW (m/s)	NS (m/s)
20	6.1	-3.5	2.6	1.5	3.5	-4.2	2.8	-5.0
22	5.4	-1.0	2.7	2.4	2.8	-2.3	4.0	-0.3
24	-4.8	3.8	1.0	-2.5	4.0	-2.4	2.2	-5.6
26	-3.7	3.0	1.8	0.6	5.4	0.6	2.4	-2.8
28	2.4	2.8	6.6	-1.2	2.4	1.9	6.0	2.4
30	0.5	3.2	2.3	-3.6	12.5	6.6	12.0	-0.2
32	5.3	1.4	7.2	1.3	17.2	0	14.8	-5.4
34	3.0	6.2	12.6	-2.2	18.6	-2.9	13.8	-7.9
36	15.9	2.8	7.4	7.8	16.5	-6.0	11.6	-2.7
38			10.5	-9.2	17.6	6.0	10.2	4.3
40			4.3	9.0	9.0	-7.0	9.0	9.4
42			21.2	0.6	14.0	14.6	14.4	6.6
44			17.7	-1.0	25.0	16.0	21.0	-4.0
46			16.3	-5.6	13.2	19.4	14.0	-7.2
48			15.0	0.1			3.4	-2.8
50			14.2	3.6			2.5	13.8
52			13.2	4.2			13.6	15.2
54			10.8	-0.8			13.2	-2.4
56			9.0	-1.0				
58			7.6	-2.6				
60								

Launch No., date, and launch time

Ht (km)	No.11(4/23)1524 EW (m/s)	No.11(4/23)1524 NS (m/s)	No.12(4/23)1728 EW (m/s)	No.12(4/23)1728 NS (m/s)	No.13(4/24)1112 EW (m/s)	No.13(4/24)1112 NS (m/s)	No.14(4/24)1504 EW (m/s)	No.14(4/24)1504 NS (m/s)
20	3.0	-1.2						
22	5.7	-0.8	4.7	-1.7	2.5	-0.3		
24	5.9	-1.0	3.2	-3.2	2.1	1.2	10.8	2.8
26	5.1	-1.3	7.0	-1.2	6.0	-3.2	2.8	1.8
28	6.3	2.3	6.4	-3.6	2.8	3.3	6.3	2.2
30	9.9	-6.6	7.6	-3.8	6.7	0	7.8	-3.0
32	12.0	-0.6	3.3	-3.3	-0.4	-2.3	0.5	3.9
34	12.5	-7.0	7.3	-7.4	4.2	3.8	10.7	-1.9
36	10.0	3.6	13.2	-2.0	5.6	-4.7	0.6	0
38	7.0	-2.4	16.9	-6.0	6.0	2.6	6.0	2.0
40	15.6	-5.2	8.0	-3.6	2.1	4.4	6.4	1.4
42	3.2	-3.0	1.2	-4.9	7.3	5.4	0	9.4
44	7.4	1.3	16.4	-3.1	8.7	3.4	8.8	4.9
46			10.1	-4.2	5.7	10.5	6.4	3.3
48							3.2	3.4
50							0.6	5.5
52							-1.2	8.5
54								
56								
58								
60								
62								
64								
66								

Launch No., date, and launch time

Ht (km)	No.15(4/27)1230 EW (m/s)	NS (m/s)	No.16(4/27)1501 EW (m/s)	NS (m/s)	No.17(4/27)1747 EW (m/s)	NS (m/s)	No.19(4/28)1158 EW (m/s)	NS (m/s)
20	0.5	2.8	2.0	0.4	6.3	1.1	3.9	-2.2
22	5.5	3.3	6.8	1.2	2.3	0	1.1	3.2
24	8.0	3.5	8.7	3.0	-2.5	-1.7	6.1	1.2
26	5.4	-5.0	2.0	-0.5	4.5	-0.7	2.3	1.8
28	4.3	2.3	5.5	0.2	7.8	-2.9	3.9	-1.5
30	6.5	-0.7	12.0	-5.6	3.0	-2.4	-1.6	-2.3
32	8.4	2.0	5.2	-2.8	4.5	-6.8	-1.0	1.2
34	-5.0	-1.7	7.5	-4.0	1.4	-3.3	3.2	3.8
36	7.9	0	10.4	-1.2	6.4	-11.1	-0.8	-2.5
38	7.0	-1.4	6.3	-7.6	2.5	-7.0	5.7	-0.8
40			0.5	-8.0	0.7	-2.3	1.3	-2.4
42			0.6	-5.5	0.6	0.3	0	1.3
44			-2.6	-0.5	-1.3	-2.5	-1.2	3.6
46			-6.1	1.0	-1.0	-4.1	-2.3	-1.7
48			-4.9	-2.5	-4.1	-5.1	-3.5	1.3
50					-3.9	-5.2	-2.2	6.6
52					-1.9	-5.0	-3.7	6.6
54					-2.5	-4.1	-0.8	4.5
56					-2.5	-0.7	4.5	2.5
58							6.0	1.0
60							4.6	0.6
62							1.4	0.6
64							-2.2	0.9
66							6.4	1.2
68								

Launch No., date, and launch time

Ht (km)	No.20(4/28)1502 EW (m/s)	No.20(4/28)1502 NS (m/s)	No.21(4/28)1659 EW (m/s)	No.21(4/28)1659 NS (m/s)	No.22(4/28)1746 EW (m/s)	No.22(4/28)1746 NS (m/s)	No.23(4/29)1140 EW (m/s)	No.23(4/29)1140 NS (m/s)
20	3.8	0.8			3.3	-1.3	2.5	2.0
22	2.8	4.2	4.8	3.0	5.0	2.8	4.4	0.4
24	5.8	-2.0	2.3	-0.9	1.1	1.8	3.8	3.2
26	0.2	5.4	4.2	-2.2	2.6	-2.2	4.4	2.5
28	-1.0	-1.6	0.5	-1.9	-1.5	-2.1	-4.8	6.0
30	2.5	0.8	1.5	1.6	0.1	-1.8	2.0	5.7
32	1.9	1.0	2.7	-0.8	5.0	0.9	5.2	0.6
34	4.0	0.8	4.0	-3.3	-3.3	-5.8	2.8	2.8
36	1.5	-4.2	-2.7	-4.4	-0.9	-0.4	1.3	4.8
38	2.0	-6.1	-2.2	-0.5	-2.2	1.3	-7.0	8.4
40	-6.8	0	-2.0	-0.2	-0.9	2.0	0	6.7
42	-2.6	-1.5	-0.9	-1.6	1.0	2.1	3.2	7.5
44	2.6	0	1.7	-1.5	1.5	1.6	7.1	6.6
46	-0.7	-1.3	1.5	1.0	4.8	0	-4.7	8.2
48	-2.5	-1.7	5.0	7.9	9.3	-3.6	-2.6	3.8
50	-0.8	-1.4	10.7	5.2	0.1	5.9	-3.0	7.0
52	1.0	-1.0	0.4	-8.3	2.5	-4.0	-2.2	12.0
54	2.7	-0.2	5.4	-1.0	-0.5	-7.8	0	13.4
56			5.0	4.0	-7.1	-4.6	0.4	12.2
58			0	-4.5	-2.5	3.5	1.2	10.0
60			-6.0	-7.6	4.0	13.7	3.0	7.0
62			12.0	6.5			5.0	3.0
64							6.2	4.0
66							7.2	5.8
68								

Launch No., date, and launch time

Ht (km)	No.24(4/29)1508 EW (m/s)	NS (m/s)	No.25(4/29)1734 EW (m/s)	NS (m/s)	No.26(4/30)1230 EW (m/s)	NS (m/s)	No.27(4/30)1528 EW (m/s)	NS (m/s)
20	4.0	-1.5			4.5	0	4.8	-4.0
22	3.0	3.6	4.0	3.4	4.2	0	2.6	-1.8
24	3.6	3.1	6.0	-2.0	2.2	5.4	3.8	0.5
26	4.0	1.8	2.0	1.8	-1.0	4.0	5.2	1.0
28	4.2	3.6	4.4	2.6	2.0	2.0	3.6	-2.0
30	4.0	-1.8			2.6	2.0	2.0	-3.4
32	-0.2	-0.2			3.5	3.5	3.8	0.4
34	1.6	1.4			4.2	0.8	5.5	-1.8
36	2.0	5.6			4.3	5.1	6.4	5.2
38	0	4.0			6.2	3.7	8.6	0
40	0	7.6			7.6	4.5	8.0	-1.8
42	11.0	0			7.0	1.8	7.0	0
44	6.0	-3.5			4.0	-0.6	0	6.4
46	-6.8	4.0			4.5	4.0	6.6	3.8
48	4.6	7.4			2.1	5.6	-5.2	2.2
50	-5.2	7.8			-1.2	7.2	0	3.0
52	-4.0	6.0			3.8	3.4	0.2	7.4
54	5.0	4.2			2.5	5.0	-1.2	11.0
56	4.6	6.6			-2.0	10.0	-0.6	10.6
58	1.0	12.0						
60	5.4	4.6						
62								
64								
66								
68								

Launch No., date, and launch time

Ht (km)	No.28 (4/30) 1718 EW (m/s)	No.28 (4/30) 1718 NS (m/s)	No.30 (5/4) 1209 EW (m/s)	No.30 (5/4) 1209 NS (m/s)	No.31 (5/4) 1518 EW (m/s)	No.31 (5/4) 1518 NS (m/s)	No.32 (5/4) 1753 EW (m/s)	No.32 (5/4) 1753 NS (m/s)
20								
22			2.7	-0.5	3.2	0	1.0	-5.5
24			-1.2	2.1	-1.0	-1.0	1.0	1.0
26			2.8	0.2	-0.8	5.2		
28			1.1	5.7	2.0	-2.4		
30			0	-0.6	1.2	-4.8	3.8	1.2
32			3.6	0	7.2	0	4.8	-2.0
34	5.7	-1.0	9.0	-1.5	9.2	-5.3	8.0	-4.0
36	8.0	-2.0	5.2	0	5.0	8.5	4.0	-2.2
38	8.6	-3.0	7.6	-2.8	5.2	-1.8	4.6	-3.0
40	5.2	-3.0	5.0	5.0	5.6	2.0	7.3	-3.3
42	-0.8	4.4	6.2	3.4	5.8	-0.3	6.0	-1.2
44	3.4	8.4	3.6	-3.2	-5.8	4.4	2.6	2.0
46	5.0	-0.2	-2.0	2.0	6.0	7.4	6.4	3.0
48	4.5	5.0	4.0	12.2	-1.6	0	7.3	2.2
50	5.2	4.0	3.0	12.0			4.4	0.4
52	7.4	-1.5	1.6	10.2			1.8	-0.6
54							1.4	0.9
56							1.4	3.4
58							1.4	6.8
60								
62								
64								
66								
68								

Launch No., date, and launch time

Ht (km)	No.33(5/4)2243 EW (m/s)	No.33(5/4)2243 NS (m/s)	No.35(5/5)1230 EW (m/s)	No.35(5/5)1230 NS (m/s)	No.38(5/6)1220 EW (m/s)	No.38(5/6)1220 NS (m/s)	No.39(5/6)1501 EW (m/s)	No.39(5/6)1501 NS (m/s)
20	5.0	-5.8					5.8	-6.4
22	-1.0	3.4			0	2.6	3.4	-1.8
24	3.0	-2.2	1.2	5.0	-4.4	-0.8	-2.0	7.0
26	-2.0	-1.2	0	-0.4	1.1	6.0	0	-2.6
28	-1.0	3.4	1.4	2.2	2.0	4.0	2.0	-0.2
30	3.2	-5.2	1.2	-2.6	-1.4	-2.8	-7.0	-1.0
32	2.4	-2.2	4.4	0.2	-1.8	4.5	3.6	8.6
34	6.0	1.4	9.2	0.8	3.3	-0.2	2.6	0.2
36	5.0	-8.4	6.0	-9.6	4.0	-0.8	3.0	-1.8
38	9.2	-3.2	4.6	-6.6	4.0	5.8	1.1	0.4
40	7.0	-5.0	3.8	-1.4	6.8	-1.0		
42	9.4	-3.4	3.2	2.2	-0.2	4.6		
44	10.4	-6.2	3.2	2.4	1.2	5.4		
46	3.0	-6.7	4.0	0.2	7.2	-3.6		
48	1.8	-8.7	3.4	-2.2	3.2	3.2		
50	0.2	-10.5	-3.8	-1.8				
52	0.5	-10.3	-4.0	0.4				
54	-8.0	-10.8						
56	-14.6	-12.0						
58	-16.4	-4.6						
60	-17.1	4.2						
62								
64								
66								
68								

Launch No., date, and launch time

Ht (km)	No.40(5/6)1730 EW (m/s)	No.40(5/6)1730 NS (m/s)	No.42(5/8)1200 EW (m/s)	No.42(5/8)1200 NS (m/s)	No.44(5/8)1546 EW (m/s)	No.44(5/8)1546 NS (m/s)	No.45(5/8)1740 EW (m/s)	No.45(5/8)1740 NS (m/s)
20	-3.4	-4.2	-4.0	1.6	-3.0	0	-3.3	-3.3
22	3.0	-5.4	0	4.0	0.4	-3.0	-3.6	1.4
24	1.0	4.2	-0.4	-2.0	-1.8	0	-2.7	0.6
26	1.2	-1.4	1.0	2.4	0	-3.2	-4.4	-3.7
28	2.4	-3.0	4.6	-0.8	-0.5	2.9	0	2.5
30	-7.8	1.0	7.5	4.5	-0.1	-1.8	2.4	-4.0
32	5.0	0	7.2	4.2	0.3	0.6	4.0	-1.2
34	5.5	-0.6	6.8	1.6	5.6	-4.7	1.0	-0.6
36	1.4	-2.6	4.6	0.2	5.0	3.9	1.6	-1.0
38	3.6	0	3.1	1.2	3.0	-5.2	1.0	-1.0
40	0.4	7.4	3.2	6.0	1.4	-4.0	0.5	-0.2
42	1.0	[illegible]	1.0	6.8	-0.8	0.3	0.8	-0.8
44	6.5	3.6	-1.4	1.8			0.8	-1.0
46	1.0	5.0	2.8	2.6			-0.7	0.2
48	0.8	4.0	0	6.4			-1.2	0.6
50	2.4	2.4	-3.8	0.2			-0.9	0
52	1.7	1.7	-4.3	7.4			-0.6	-0.3
54	-1.0	3.1					-0.5	-0.6
56	-2.6	5.6					-0.4	-0.5
58	-3.4	8.2					-1.0	-0.4
60	-3.1	11.5					-1.6	0
62	-2.5	15.0					-1.8	0.8
64							-1.9	1.8
66								
68								

END 6/66